City of Corvallis
Salmon Response Plan

Prepared for:

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Appendix 10

Monitoring Report Format and Methodologies

MONITORING REPORT FORMAT AND METHODOLOGIES

MONITORING REPORT FORMAT

The following outlines the format and content of the monitoring report to be prepared for submission to NOAA Fisheries. It describes the actual data to be collected and the assessments to be performed. This format can be used as a "programmatic " approach, in the sense that non-specific citywide activities can use this approach, as well as specific point-type rehabilitation projects.

The report will include the following information:

I. Project identification.

Should this format be used simply to report on the City's progress toward PFC, the purpose simply states that.

(1) Permittee name and project name.

This element identifies the City of Corvallis (or some other entity) conducting the monitoring assessment of citywide activities, or specific rehabilitative projects undertaken. It is assumed that should a non-City organization wish to undertake a rehabilitative action, this would be done under the aegis of the City's agreement with the regulatory agencies and so would fall under the City's monitoring plan. Even if it did not, this format is appropriate, as it is NOAA Fisheries-approved. It also allows for easy integration into the City's overall planning and compliance process.

(2) Type of activities undertaken and expected outcomes.

Again, under the citywide monitoring the activities undertaken need to be described. The outcome should not be stated in highly quantitative terms, but rather strictly as addressing a reduction or change in some undesired outcome of activities. Should the project be point- or reach-specific, the desired elements of the baseline need to be described, as well as a description of anticipated changes.

(3) Project locations.

Again, locations for specific projects may be point-, reach-, or even basin-specific.

(4) Contact person.

This should be fairly self-explanatory.

(5) Starting and ending dates for work completed.

This especially applies for specific rehabilitative activities undertaken under the ESA 4(d) umbrella. Certainly, citywide changes to operations and codes need not address the end date. Statements here should consist of those addressing when monitoring begins, what the current baseline for the parameters of interest is, and what the timeline for changes should be at the scale of interest.

II. Photo documentation.

Photographs of habitat conditions at the project and any compensation site(s), before, during, and after project completion throughout the life of the project. Include general and close-up views showing details of the project and project area, including pre- and post-construction. Existing photographs taken as part of the baseline data collection can be used as pre-project photographs for citywide actions.

Relevant habitat conditions may include characteristics of channels, eroding and stable stream banks in the project area, riparian vegetation, water quality, flows at base, bankfull and over-bankfull stages, and other visually discernable environmental conditions at the project area, and upstream and downstream of the project area.

Label each photograph with date, time, project name, photographer's name, and any pertinent comments.

III. Other data.

Additional project-specific data, as appropriate for individual projects. While this section specifically refers to rehabilitation projects, it is also applicable to general, citywide changes on a programmatic scale. Again, the critical element is to describe the spatial and temporal scale of the processes of interest and the changes to be made, and then supply a general description of outcomes. Care should be taken to explicitly describe the timeframe for expected change, as there frequently exists a misunderstanding as to how long changes actually take to manifest themselves in the system, plus a description of what this 'manifestation" would look like.

(1) Site preparation.

(2) Site restoration.

(3) Isolation of any in-water work area, capture and release.

This section becomes important only if any in-water work needs to be done. Instream projects will likely require some form of extended Section 7 consultation unless they are specifically named in the ESA 4(d) plan and accepted as such.

(1) Supervisory fish biologist – name and address.

(2) Methods of work area isolation and take minimization.

a. Stream conditions before, during, and within one week after completion of work area isolation.

b. Means of fish capture.

c. Number of fish captured by species.

d. Location and condition of all fish released.

e. Any incidence of observed injury or mortality.

f. Notification made to the NOAA Fisheries Law Enforcement Office, located at Vancouver Field Office, 600 Maritime, Suite 130, Vancouver, Washington 98661; phone: 360-418-4246, and the following of required protocols for handling injured or dead fish.

IV. Monitoring site location.

(1) Meta-reach

(2) Habitat types (description of reach of interest)

(3) Channel cross-section (A-E)

(4) Location of nearest thermistors (upstream and downstream)

(5) Water Quality parameters of interest. Identification, baseline values, study design, scales of variability in system of interest. Sampling procedure, analytical procedure (laboratory).

V. Baseline data for site.

The baseline data section should contain whatever data exist to describe the current condition of the site(s) in question. This includes maps, site drawings, project design, and photos. This also includes the classification data listed above, any water quality information available from the City or other sources.

This section should make reference to the rationale for sampling at the appropriate scale for the parameters of interest stated earlier in this report. This often becomes a point of confusion for both those doing the monitoring and those receiving the report.

VI. Analytical procedures.

This section includes a description of the proposed or existing action or conditions, an assessment of the desired outcome, a description of the sampling design and analytical design, and the methodologies used.

VII. Monitoring data collected.

Monitoring data includes data tables

VIII. Results.

This section contains outcomes from the analysis. Any statistical results get discussed here.

IX. Discussion of Monitoring Outcome.

What was it like before, what was the goal of the effort undertaken, what should this goal look like (in terms of any existing baseline), and was the goal achieved? If so, why? If not, why not? If the activity failed to meet its goal, a discussion of further rehabilitative efforts is in order here.

METHODOLOGIES

Stream Geomorphology

- Widths/depths
- Substrate
- Pool/riffle
- Pool Quantity/quality
- Gradient

Identified Instream Habitats

- Habitat types
- Habitat length; estimated and measured
- Habitat width; as above
- Maximum depth
- Number of pools
- Depth at Pool Tail Crest-estimated and measured for every pool habitat
- Stream Bed Substrate; Wolman pebble count
- Cover type; dominant and subdominant
- Bankfull width; measured at each n^{th} riffle
- Bankfull Depth; measured as above, taking three measurements across the channel
- Embeddedness; estimate percentage for each measured pool, riffle, and glide.
- Stream bank ground cover; estimated for the upper one-third of the stream bank for each n^{th} habitat unit
- Riparian vegetation; seral class within the inner zone for each n^{th} unit
- Dominant and subdominant conifer and/or hardwood species for stream bank
- Seral stage for outer delineated zone

Stream Geomorphologic Process Classification

Rosgen's classification involves a four-level hierarchy, beginning with a geomorphic characterization, to determine the number of stream channels followed by a morphological description. The third level involves an assessment of a stream's condition. The fourth contains a level of validation. Each level rests on the information derived from the previous level. The first two levels rely heavily on conditions during bankfull discharge.

General questions include the following from Rosgen's classification:

- What are the stream's entrenchment ratio, width/depth ratio, sinuosity, and slope?
- What is the dominant material that lines the stream channel?

Channel process determination uses a diagnostic framework developed by Montgomery and Buffington (2002). Prediction of the impacts of multiple conditions on stream channels and assessing their response potential requires consideration of differences in channel type sensitivity, and spatial and temporal variability in inputs to the channels.

1. Number of Channels

This information can be determined from topographic maps, aerial photographs, or from field observation. The situation is direct. Does the water flow through only one or through several channels? If it has several channels, it is either called braided (D) or anastomosing (DA)? If there is a single channel, it can vary in its sinuosity?

2. Determination of Bankfull Depth and Width

This involves assessing the elevation where the channel, under bankfull discharge conditions, ends and the floodplain begins. The indicators used to assess this elevation are as follows:

- The top of the point bar (the elevation where channel deposits end),
- A change in vegetation (especially the lower limit of perennial species),
- Slope change in channel cross section,
- Top of the undercut slope (the elevation where channel erosion ends),
- Change in particle size (where soils end and sediments begin), and
- Drift lines and watermarks.

Some channels cut deeply into their floodplains, leaving steep banks on either side. Other channels gradually pass to their adjacent floodplains. This is measured using the entrenchment ratio. This is determined by field measurement.

Entrenchment Ratio = (Bankfull Maximum Depth) ÷ (Flood-prone Area Width*)

*Flood-prone Area Width is the width at twice the maximum bankfull depth.

3. Width/Depth Ratio

Some channels are wide and shallow. Others are deep and narrow. This is assessed by the width/depth ratio parameter.

Width/Depth Ratio = (Bankfull Surface Width) ÷ (Bankfull Mean Depth*)

*Bankfull Mean Depth determined from 20 equally spaced depth readings taken from the bankfull stage to the stream bottom.

4. Sinuosity

This parameter refers to the winding of the stream. Is the stream channel straight or does it meander intensely?

Sinuosity = Stream Length ÷ Valley Length

Or,

Sinuosity = Valley Slope ÷ Channel Surface Slope

A preliminary value can be determined from a topographic map. A field value is surveyed from an "established channel reach" which is the length of the channel's flowpath and is 20 to 30 times the value of the bankfull channel width.

5. Slope

Slope refers to the steepness of the stream surface along its flowpath. The measurements needed are surveyed in the field, though topographic maps may provide a rough estimate. Slope is calculated by dividing the vertical change in water surface elevation by the length of the stream as it passes through at least two meanders or along a distance equal to 20 to 30 bankfull channels widths.

6. Channel Material

This assesses the material over which the water flows and is determined by field observation. This includes: a) bedrock, b) boulders, c) cobbles, d) gravel, e) sand, or d) mud (i.e., silt and clay). The determination of channel material can be refined, beyond casual observation, by using the "established channel reach" (i.e., 20 to 30 times the bankfull channel width or two whole meanders). A reach is subdivided by environment (e.g., riffle and pool, main channel and backwater, undercut slopes and slip-off slopes) and the percentage of each environment is estimated. The number of samples taken at each environment of the "established channel reach" is based on the percentage of that environment. For example, if the riffles make up 10% of the "reach" while pools make up the remaining 90%, then 10 samples are taken in the riffles and 90 samples are taken in the pools. The reach is then characterized either collectively by the weighted average of all environmental percentages or separately by environment.

Properly Functioning Condition

Properly functioning condition consists of flows governed by infiltrated groundwater, overland flows, and source flows (e.g., springs, lakes, etc), with diverse instream habitat types. System hydrographs have fewer peaks over a longer period (i.e., bankfull flows occur on the order of two per five-year interval). As encroachment occurs in floodplains, streams become stormwater conduits. This, and the removal of large woody debris (LWD) from the channel, increases channelization. Loss of floodplain and restriction of channel cause loss of off-channel habitat. Channelization causes increased velocity and increased down-cutting erosions. It severs connections between stream flow and groundwater, causes problems in the hyporheic zone, and increases problems for spawning and rearing fish. Channelization also degrades instream cover, off-channel and other refugia habitat, riparian conditions, hydrologic connectivity, food resources, substrate, and instream habitat quantity, diversity, and quality.

An increase in impervious surface leads to greater amounts of overland flow, as opposed to infiltrated groundwater, as the source of water in the stream. Overland flows create a greater amount of water in the stream in a shorter period. Runoff from impervious surface causes increased instream erosion as the stream equilibrates to the new flow regime. This leads to loss of instream habitat features (e.g., under-bank cover) through erosion, and transport of LWD. It also increases fine sediment initially, while the stream is equilibrating (0 to 20 years). Once the stream reaches its new equilibrium, fines actually decrease (assuming no channelization; this activity stops the channel from reaching equilibrium).

The principal effect of the increased flows is to widen the channel. This occurs because the stream must accommodate these greater flows. Bankfull width increases and pools fill in. Stream flow slows and temperature increases, due to the slower passage, loss of riparian shading, and greater surface area to be heated. Continued erosion causes the loss of overhanging cover in the pool areas. Increased sedimentation and the subsequent slowing of flows and filling of pools by finer sediments cause a loss of spawning and rearing habitat. As the channel reaches equilibrium, the higher flows flush the finer sediments away. This leaves coarser sediments, which may be better for spawning activities, but spawning activity is diminished if the connection between the groundwater flows and surface flows is severed as the result of changes in the hyporheic zone. The higher flows may also wash fish away and the lower flows may strand them in summer when rearing is important.

Pathways

Riparian Areas (Buffers)

Properly functioning condition consists of buffer widths, continuity, and structure sufficient to provide stream bank erosion protection, LWD, filtration of overland flow, and shading. Densely vegetated riparian areas act as filters for contaminants and nutrients, as well as infiltration areas to regulate flows. Riparian areas provide LWD, an important contributor to instream habitat structure and formation. They also provide shade for the adjacent stream, prevent bank failure, and create instream bank cover for fish.

Riparian areas function to preserve or enhance water quality by regulating temperature and by filtering contaminants, sediments, and nutrients. Temperature plays a critical role in the regulation of fish physiological function. The Clean Water Act sets temperature limits for cold-water fish species (e.g., salmonids). The presence of vegetation serves to create cool-water refugia microclimate areas for fish to escape generally warmer temperatures in other portions of the stream. Under the appropriate shade and flow regimes, streams may even cool down. This makes this portion of the water quality element more important. Riparian areas regulate temperature by shading the stream. Tall conifers perform this function best, but any woody or even tall herbaceous vegetation along the stream bank or on a south slope will do this, depending on the size of the stream. Elements important to this function include vegetation type and height, stream width, stream orientation and stream flow.

Riparian areas indirectly influence fish habitat through temperature and filtration effects, as well as the securing of the stream banks; an under-appreciated function of grassy banks. This reduces the collapsing of the banks, allowing the stream to undercut them and thereby creating fish habitat. This undercut bank habitat also may serve as a cool-water refugium. The prevention of instream erosion and the filtration of sediments keep important habitat features, such as spawning gravels and rearing pools, from silting in. This prevents mortality of the eggs from anoxia. It also maintains pool depth, which prevents summer mortality.

LWD serves an important role in stream habitat modification by creating pools and other instream habitat features, as well as substrate for invertebrates; potential food sources. Important elements in this function include riparian continuity (estimated by impingement), which also plays a role in nutrient and habitat inputs to the stream, riparian buffer size (as a nutrient source and a source of groundwater flow back into the stream), and vegetation type (LWD and shading).

Barriers

Barriers to fish movement include such structures as culverts and pop-up dams. Culverts create an environment where flows become considerably more powerful, but also may serve as low-flow barriers to movement. Dams without fish passage serve as blockage to movement during all flow regimes. Barriers prevent adult fish access to spawning habitat at low flows, they do not allow juveniles access to rearing and refugia habitat, nor downstream passage.

Contaminants

Contaminants in the water may have a direct effect, through toxicity to one or more life stages of the fish or other elements of the food web, or indirect effects, such as sublethal impacts on growth and vitality. Trying to separate sublethal effects from background individual variation within a population, as well as from seasonal changes provides the greatest challenge facing regulatory biologists. These effects can, however, be highly important in the long-term survivability of the population, as their impact tends to fall on lifetime reproductive output; usually through effects on growth, reproduction, sensory or motor functions, or food supply.

VARIABLES OF INTEREST

Physical Parameters

Land Cover and Land Use

The important first step in any watershed analysis identifies the controls (i.e. ecoregion and climate), as well as human infrastructure alterations (which function in a manner similar to the geology) acting to constrain the system at this hierarchical level. The next step classifies land cover/land use (LC/LU), again at the watershed scale, using a recent aerial photo or existing GIS coverage and classifying the systems as: upland and riparian, based on the location of the 100-year floodplain, at least at this scale, and terrestrial or aquatic (lotic or lentic). The next step, vegetation classification builds upon these categories, but also includes subdivisions for forested, non-forested (clear-cut) shrub-sapling, herbaceous, or developed, with appropriate lower hierarchical descriptive terms as necessary. The assessment also identifies slopes and soil for this spatial level.

The use of historical conditions identified from aerial photograph interpretation, and/or existing GIS layers facilitates the determination of causal mechanisms for identified patches as well as provides an indication of past trajectories of change. At this scale, certain LC/LU characteristics (size, number, and location) will likely swamp smaller patch characteristics in terms of importance. At this stage, the analysis may conclude that gross level changes provide sufficient information to correlate potential outcomes at a scale appropriate for the City monitoring purposes identified earlier. Should this not prove the case, the analysis needs to move to the next lower level, which provides detail.

The preceding analysis identifies the controls occurring at each level of interest. It also allows the prediction of the expected trajectory of current succession, and the inputs necessary for this succession to proceed in a desired direction. Determination of succession trajectories uses analysis of historic changes, current conditions, and their role in the future, as well as knowledge of the ecological traits of the individual dominant and subdominant species (autecology) and the assemblage (synecology). This facilitates determining the fate of the various patches or habitat elements, as well as correlations between natural and anthropogenic conditions and habitat effects.

At this next smaller scale, the LC/LU elements break into smaller patches, with more precise vegetation and land use classification. Analysis at this hierarchical level provides much grater detail, and subsequently much finer-scale correlations between outcomes and land uses. At this scale, slope, as measured from the top of the stream bank, separates the upland and zones. Upland area slopes exceed two percent. LC/LU classifications also expand considerably, encompassing a number of subclasses. Observers should use existing topographic maps and county soil surveys to classify slopes and soil types. Finer scale details of changes in water quality from changes in land use will usually correlate with the variables below.

The approach then looks at the features of the chosen reaches to establish the least resilient habitat elements (effects) at this scale. These generally consist of stream geomorphologic and functional criteria. The Rosgen stream classification methodology provides an excellent indicator of current geomorphic conditions.

A reach response classification provides a framework for assessing the functional status of the reaches in question, source, transport, or response. Classification of segments into source, transport, and response reaches using gradient criteria of >20 percent for source, 3-20 percent for transport, and <3 percent for response reaches reveals general patterns of sediment (or other material) transport characteristics. Source reaches are likely to be storage sites for colluvium and are subject to debris flows and mass wasting events. Transport reaches are likely to act as conduits for rapid sediment transport and delivery to downstream reaches. Response reaches are depositional areas that are continually readjusting in response to changes in sediment/material.

The Montgomery-Buffington (M-B) classification system (Montgomery and Buffington 1993, 1998) is an extension of the above approach, providing detail on the various functions of the stream reaches. Each reach within a stream network produces a limited (and different) range of habitat characteristics depending upon its position within the drainage network and site-specific physical characteristics. Flow interacts with the geology of the watershed and produces instream habitat effects such as size and distribution of substrate, the distribution and abundance of riffle-pool complexes, the residual pool depth, and the amount of instream cover. The M-B classification fits well into a later diagnostic approach to functional change with disturbance developed by Montgomery and McDonald (2002). This system (M-B) requires a greater attention to detail, and field data collection and analysis.

Sediment and Surface Erosion Assessment

Sediment source classification uses three general categories: sediment derived from fields and slopes (referred to here as upland erosion), from stream banks, and from mass wasting. Sediment load allocations address the first two (mass wasting, including landslides and debris flows, may comprise a lesser source of sediment, although recent watershed assessment theory suggests otherwise). Sediment transported to streams, and the load carried in streams makes up the other important sediment sources.

Hillslope erosion occurs on slopes where detachable soils on moderate to steep slopes get exposed to rainfall and overland or surface flow. Sediments generated by surface erosion processes can affect water quality and aquatic habitat. Human activities that result in soil compaction, or where site preparation or harvest activities reduce the surface organic layer increase the occurrence of overland flow.

Factors determining the susceptibility of soil to erosion include type and amount of vegetation, topography, climate, and soil properties such as cohesiveness, infiltration rates, and texture. The analysis of the relative potential of hillslope-related surface erosion for this watershed analysis area uses a soil erosion potential map incorporating topography (slope steepness) and soil erodibility (soil K-factor). The K-factor provides a relative measure of the erodibility of bare, freshly tilled soils.

In-channel storage and release comprises another category of sediment position. In-channel sediment partly results from the balance between deposition and re-suspension; broadly accounted for by the model calibration of soil loss to instream total suspended solids.

Eroding Stream banks

Recent studies indicate the understatement of the contribution of stream bank erosion to total sediment yield (Rosgen 1996). The relative contribution of stream bank erosion to upland erosion also gets displayed in the watershed sediment load allocations. A better approach for identifying the desirable percentage of eroding stream banks establishes a relationship between substrate fines and eroding stream banks for the basin of choice. A tremendous difficulty demonstrating a quantitative improvement in the streambed grain-size distribution (due to the large amount of spatial and temporal replication required for sampling) renders any prediction concerning the amount of erosion necessary at the watershed or sub-basin scales difficult. However, any reduction of fine sediment in a stream should improve substrate conditions, or at least maintain the status quo.

Turbidity

Turbidity measures water cloudiness. In streams, suspended particles and/or organic material make up turbidity. The analytical method compares the intensity of light scattered by the sample under defined conditions to the intensity of light scattered by a standard reference suspension under the same conditions. Measurement, whether the standard NTUs (Nephelometric turbidity units) or the less common JTUs (Jackson turbidity units) and FTUs (formazin turbidity units), uses a Nephelometer (a meter constructed for the purpose) in the case of the former and spectrophotometers (such as those found in Hach kits) for the latter two. No correlations exist among the measurements making impossible any conversions from one scale to another.

Turbidity provides a simple indirect measure of total suspended sediments in streams, however the specific relationship varies depending on such factors as the solids' types and sizes. As a result, impacts of suspended solids and turbidity on aquatic life often get evaluated together. Many studies relate the size of substrate sediment particles to the survival of embryos and/or alevins and the emergence success of fry. Waters (1995) provides a useful review of sedimentation in streams.

Riparian and Upland Vegetation

Riparian vegetation influences both channel stability, and the composition of streambed substrates. The relationship of riparian vegetation with temperature, habitat modification, and streambed fines means that measurements of it often serve as an indirect index of these features. Properly functioning riparian condition, as it relates to watershed health, consists of buffer widths, continuity, and structure sufficient to provide stream bank erosion protection, large woody debris, filtration of overland flow, and shading. Densely vegetated riparian areas filter contaminants and nutrients, as well as provide overland flow infiltration areas and thereby influence base flows. Riparian vegetation also provides LWD, an important contributor to instream habitat. Important elements for this function include vegetation type, buffer width, continuity, soil moisture, and slope.

Temperature

Stream temperature represents an important water quality parameter that directly and indirectly affects aquatic organisms (Isaak and Hubert 2001). Stream heating results from the interaction of channel dimensions (width and depth), shade (reduction of incoming solar radiation), groundwater or hyporheic exchange, and solar radiation (Liquori and Jackson 2001). Therefore, riparian vegetation, stream morphology, hydrology, climate, and geographic location influence stream temperature. While climate and geographic location remain outside of human control, land use activities influence the integrity of riparian condition, channel morphology, and hydrology.

The influence of complex geomorphologies on stream temperatures renders paired-basin studies difficult to analyze, as nearby streams often demonstrate markedly different temperature regimes. Interestingly, studies show that removal of upstream vegetative cover, or conversely, providing shade influences local or stream reach temperatures very little. In other words, stream temperatures reflect local heat equilibrium; there exists no cumulative effect (Zwieniecki and Newton 1999 in Liquori). Human activities contributing to degraded water quality conditions include agriculture, forestry, roads, and urban and rural riparian development disturbance. Riparian vegetation especially influences the stream microclimate through its shading capability and its influence on channel morphology.

Conductivity

Conductivity (specific conductance) measures the ability of the water to carry an electrical current. This measurement permits comparison of basin characteristics with the influence of discharged substances. Conductivity represents a conservative measurement of dissolved solids as influenced by basin characteristics and not easily altered by other processes. As such, an investigator should find similar ranges of values throughout the watershed. Changes in conductivity seen during stormflows usually result from such activities as increases in impervious surface: The stream carries materials in the surface waters that would normally infiltrate into the groundwater.

Alkalinity, pH, and Hardness

Alkalinity represents the acid-neutralizing capacity, or resistance to changes in the pH, or level of acidity. Hardness represents the presence of calcium and magnesium. The pH of a river or lake reflects, in part, the level of photosynthetic activity. All three factors reflect the influence of bedrock types on the stream in question. For instance, Coast Range bedrock generally consists of marine sedimentary origins, as opposed to the more resistant granitic bedrock of the Cascades. Coast Range streams generally contain higher levels of alkalinity, pH, and hardness (softer).

All three factors tend to increase in a stream as it flows from high to low, due to increased contact with bedrock. Usually, high levels of algae and other aquatic plants will cause the pH to increase, while precipitation tends to lower it (more acidic). Urbanized watersheds generally show an increase in the ability to neutralize acids due to their contact with a greater surface area of erodible calcium (i.e. concrete). Of these three factors, only pH directly influences fish and stream invertebrates.

Dissolved Oxygen

Changes in stream structure producing temperature changes also influence dissolved oxygen levels. Rapids cause some water aeration. A combination of decreased flows, increased shallow pools, and higher temperatures produces lowered dissolved oxygen concentrations. This increases the stress on fish, and could result in decreased life expectancy.

Dissolved oxygen concentrations also provide an indicator of the level of photosynthesis and decay occurring in a river or lake. Increases in nutrients produced by fertilizers and other organic materials transported into the stream by runoff may cause increased algal or macrophyte production. Die-offs of vegetation, whether natural or caused by herbicides transported into the system, and the resultant breakdown of this organic material, also lower dissolved oxygen in the stream. Daylight and nighttime dissolved oxygen measurements reflect mostly photosynthetic processes and decay processes, respectively.

Biological influences on water quality

<u>Chlorophyll *a*</u>

Chlorophyll *a* concentration in the water column indicates the level of suspended algae production in a river or lake. Release water from reservoirs typically contains greater concentrations of chlorophyll *a* than do unregulated main channels. Exceptions to this depend upon timing of releases (prior to the onset of production) and the speed and turbulence of flows in the unregulated channels.

<u>Bacteria</u>

E. coli bacteria indicate fecal contamination in a river. *E. coli* occupies the guts of mammals. Potential sources of bacteria load, in addition to general overland runoff, include confined animal feeding operations (CAFOs), urban runoff, and failing septic systems. The general literature indicates relatively minimal bacteria contributions from forested and range lands. Much larger values exist for urban and agricultural areas. Likely sources of fecal contamination in the streams likely consist of failing septic systems and livestock.

<u>CBOD</u>

Water column carbonaceous biochemical oxygen demand (CBOD) represents the oxygen consumed by the decomposition of organic matter in water. The sources of the organic matter vary and result from either from natural sources (e.g. direct deposit of leaf litter), or from anthropogenic sources (e.g. polluted runoff).

<u>Sediment Oxygen Demand (SOD)</u>

When solids containing organic compounds settle to the bottom of a stream they either decompose anaerobically or aerobically. The oxygen consumed in aerobic decomposition of these sediments, called sediment oxygen demand (SOD), represents another dissolved oxygen sink for a stream. The SOD may differ from both water column CBOD and nitrification in that it can remain a dissolved oxygen sink for a much longer period following the initial discharge (e.g., organic-containing sediment deposited as a result of rain-driven runoff may remain a problem long after end of the rain event).

Algal Growth

Excessive algae concentrations can cause large diel fluctuations in dissolved oxygen. Such streams generally exhibit supersaturated dissolved oxygen concentrations during the day and low concentrations at night. The State of Oregon designated an action level of 15-ug/L concentration of chlorophyll *a* (a measure of algal content) to indicate when algal growth may be a problem.

Water Chemistry variables of potential interest

Agricultural Chemicals

Despite a long-term focus on the problem of herbicide transport in surface runoff from agricultural application, until recently little detailed investigation of the transport of herbicides in surface runoff from roadside applications exists in the literature. Because of the NAWQA program, the USGS measured the concentrations of urban, rural, and forest chemicals in select water bodies across the country.

Despite the development of virtually all of the basic theory of herbicide entrainment and transport in runoff in an agricultural context, most of this information and models apply directly to the other applications, particularly those related to the time periods following application (rainfall timing, intensity, and duration, and total runoff volume-pounds).

The first significant runoff nearly always removes the greatest amount of compound. An often almost exponential decline in the total amount of the compound removed, as well as the runoff concentration with subsequent events, follows this initial rainfall event.

The availability of a compound for transport also usually declines with time even in the absence of precipitation through 1) a decrease in the total amount of compound stored in the surface layer of the soil (degradation), 2) a decrease in the readily mobilized fraction through slow, progressive adsorption onto the soil matrix and/or 3) a migration to more strongly binding adsorption sites. A longer lag time between compound application and the first runoff event decreases the amount of the compound removed by that event.

Nutrients

Bioavailable nitrogen and soluble reactive phosphorus, limited in freshwater systems, tend to drive biotic activity in rivers and lakes. Elevated nutrient levels tend to produce increases of periphyton (the filamentous green algae that attaches to rocks or wood). Under certain conditions increases in nitrogen or phosphorous may also cause an increase in diatoms and blue-green algae.

Nitrogen

Nitrogen, often considered as limiting to plants in terrestrial and aquatic systems, comes from either the atmosphere through fixing by blue-green bacteria (a small amount), or through oxidation by plants, animals, and decomposers (a much larger pool). In aquatic systems, dissolved and particulate nitrogen make up the more useful forms. Nitrate, nitrite, and ammonium contain the nitrogen immediately available for use by stream plants and animals.

<u>Ammonia</u>

Ammonia, the reduced form of nitrogen, exists in two states in natural waters: ammonium ion (NH_4^+) and un-ionized ammonia (NH_3). Un-ionized ammonia generates much more toxicity to aquatic life than the ionic state. Since the un-ionized fraction of ammonia increases as pH increases, systems with relatively high pH show a high susceptibility to ammonia toxicity. Concentrations of ammonia acutely toxic to fishes may cause loss of equilibrium, hyperexcitability, increased breathing, cardiac output and oxygen uptake, and, in extreme cases, convulsions, coma, and death. At lower concentrations, ammonia also affects fishes by reducing hatching success, growth rate and morphological development, and causing pathologic changes in tissues of gills, livers, and kidneys (EPA 1985).

<u>Nitrate and Nitrite</u>

Nitrate and nitrate form when nitrogen (usually in the form of ammonia) gets oxidized. This combination occurs in nature when nitrogen in the air reacts with oxygen or ozone, but this produces relatively small amounts, compared with that oxidized through the action of bacteria.

Naturally occurring levels of nitrate in surface and groundwater do not generally exceed 2 milligrams per liter (mg/l), hence its potential for limiting plant production. Greater amounts eventually contribute to the phenomenon of eutrophication, where plant production increases considerably and the corresponding production of detritus exceeds the capability of aerobic bacteria to break it down and recycle the nutrients into the system. The concurrent loss of oxygen from the process leads to a great increase of anaerobic bacteria, producing an anoxic (airless) zone at and/or near the bottom of the water body. The EPA considers water with less than 10 mg/l nitrates as nitrogen (NO_3 -N) as generally safe for use in foods and beverages.

Elevated nitrate levels result from anthropogenic sources such as fertilizers, septic systems, animal feedlots, industrial wastes, and food processing waste, or naturally from certain geological settings or decaying organic matter. Elevated levels of nitrate found in well water usually indicate improper well construction or location, overuse of chemical fertilizers, and/or improper disposal of human and animal waste.

Total soluble nitrogen consists of bioavailable nitrogen and nitrogen not immediately available for uptake (i.e. nitrogen leakage from aquatic plants in the river). In western Oregon river systems, total soluble nitrogen concentrations appear spatially constant, and highest in mid-summer. In regulated streams, water released from mainstem reservoirs generally contains higher concentration of total soluble nitrogen than the downstream river reaches. This results from greater primary productivity occurring in the reservoirs.

Soluble Reactive Phosphorus (Orthophosphorus)

The soluble reactive phosphorus usually represents the limiting nutrient in western rivers, except in areas with high anthropogenic inputs (usually from sewage treatment plants or septic systems and from agricultural or forest fertilization) or with high phosphorous-containing bedrock. Types of phosphorous found in aquatic system include, organically bound phosphorous, inorganic polyphospates and inorganic orthophosphorus. Non-polluted systems generally contain total phosphorous concentrations of less than 0.1 mg/l and inorganic phosphorous soluble concentrations of less than .001 mg/l. Runoff concentrations resulting from fertilization tend to increase immediately after rainfall events following application (as outlined above in the section on agricultural chemicals), while the sewage-based concentrations increase more slowly, representing a more chronic input.

Soluble reactive phosphorus concentrations generally decrease downstream in western Oregon rivers. Mainstem reservoirs form a sink for soluble reactive phosphorus, as it binds to organic and inorganic particles often producing an internal phosphorous cycle that continues to supply this limiting nutrient despite the cessation of any anthropogenic inputs. Algal growth in the reservoirs tightly cycles the available phosphorus causing only a slight increase in reservoir outflow concentrations during mid-summer and early fall.

Dissolved Organic Carbon

Dissolved organic carbon from the decay of wood, aquatic plants, and other organisms provides an essential component for plant growth within the river channel. Concentrations generally remain relatively constant in most regulated streams, with little influence from reservoir release water, and then drop to the lowest in September during the attached algae and macrophyte production maximum.

Heavy Metals

Metals present in aquatic systems present both beneficial and harmful effects, as the presence of even those necessary forms can cause lethal or sublethal impacts to living organisms if in high concentrations. These include copper, zinc, lead, arsenic, and manganese. High heavy metals in water often indicate pollution from manufacturing processes or mines, as well as from the effluent of sewage treatment plants. However, some high heavy metal concentrations, such as mercury, iron, and copper, originate from concentrations in the underlying bedrock.